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ABSTRACT

A meta-analysis of theoretical debates concerned with the assessment of risk associated with the use of nuclear power as an energy source is presented in this paper. Based on a central premise that risk assessment has a direct impact on national policy decisions and is associated with different perspectives reflective of different social sectors, it is hypothesized that national policy decisions mirror an economic imperative, whereby economic cost is a better predictor of policy decisions than is consideration for human safety. Examples of this view are given including the belief that (1) the cost of safety regulations represent an impediment to technology and hence the economic well-being of the nation; and (2) the notion that quantitative risk-benefit analysis, in which possible costs and benefits of policy decisions are quantified and assigned a financial value, plays an increasing role in policy decisions. Public opinion is then addressed as a variable with potential cost attached to it. Research focusing on bias or individual heuristics that systematically color the public's prediction of the risk associated with hazardous events is followed by a discussion of error variance, expert bias and infallibility of expert opinion, and the use of Bayesian statistics. It is concluded that because different sectors of society are differentially impacted by policy issues, there is a need for greater political balance in prestigious committees concerning risk assessment and policy decisions. (LH)

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Risk Assessment: An Examination of Assumptions

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rewrite 9/85 incorporating Wildavsky's suggestions

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This paper presents a meta-analysis of theoretical debates engendered by assessment of risk associated with use of nuclear power as an energy source in the United States. The central premise of this paper is that risk assessment has direct impact on national policy decisions and is associated with different perspectives reflective of different social sectors (Hamlett, 1984). Complexity arises from the empirical fact that complete information about potential outcome of technological risks is lacking, leaving large areas of uncertainty (Wilson, 1984).

It is the premise of this paper that ongoing conditions of uncertainty regarding, on the one hand, the increasing problem of limited energy resources and, on the other hand, actual effects of ionizing radiation on humans and technology maintains controversy associated with differing social definitions of knowledge and value priorities.

It is hypothesized that a major underlying juxtaposition is the relative significance of economic and individual safety in our national policy. This justaposition has become more apparent, particularly in the nuclear industry, with the potential magnitude of the physical safety risk brought to awareness by the accident at the Three Mile Island nuclear facility considered to be the worst nuclear accident in United States history (Davies, 1984). Examination of the stated rational behind policy decisions suggests that embedded in these decisions has been an underlying operating principle of economic imperative that superseded the often stated commitment to human health and safety which is consistent with public conceptions of morality.

One example of the economic imperative is present in the 1983 Supreme Court decision to uphold California's state right to ban further construction of nuclear

plants on the basis of unpredictable future costs. This decision drew criticism which stated that the real concern was the safety of nuclear energy, not its economic health (Greenhouse, New York Times, March, 1983). Two Supreme court Justices refused, in fact, to concur with Justice White's written opinion on this issue stating that it did not go far enough in the freedom it gave the states to regulate nuclear power, and that there was no basis for a distinction between safety and economics.

A second example of the economic imperative was reflected in the N.R.C.'s vote to let the Indian Point plant in New York operate although an emergency plan had not been effected (May, 1983). Chairman of the N.R.C. Palladino's explanation of the decision reflected the relative weighting of safety and economic factors impacting on this decision. In his words, "it is highly unlikely that an accident would occur at Indian Point; if one did, it would probably allow 12 or more hours for response action; and if this were not the case, staying in one's house would probably be preferable anyway" (May, 1983). Regarding economics, he stated the following: "Finally, I cannot ignore the economic cost of shutdown. While the exact amount of these costs can be debated, they are significant, and give added weight to the above reasons for not shutting down the plant" (May, 1983). In short, the physical threat to human safety posed by nuclear commercial technology was outweighed in policy decision by the financial imperative that economic cost is a graver threat.

This perspective has been clearly articulated by Wildavsky (1980) who asserts that safety regulations and expenditures result in reduced national income, which indirectly produces negative health effects. Wildavsky (1979) maintained that the cost to the consumer in higher prices imposed by safety regulations is enormous. According to Whipple (1981), while direct health effects of safety regulations and expenditures are favorable, these same regulations and expenditures result in

reduced incomes, which indirectly produce negative health effects.

Integrally related to an economic imperative is a technological imperative in our society that operates with its own momentum, and which is mandated by a set of autonomously functioning principles and values (Slater, 1972; Ellul, 1972, 1980). These principles and values define unencumbered technology as essential to economic or corporate survival. Corporate survival through unencumbered technology has been seen as essential to the economic survival of the nation, this in turn being referred to as national security. Hamlett makes reference to this perspective as the "dominant configuration" or "military-industrial complex" (1984).

The assumption that advances in technology are essential to our economic security as a nation were clearly articulated on April 14, 1983 by a 22 member panel assembled by the National Academy of Sciences. The panel, comprised of high corporate officials from technological industries, university presidents, financeers, and academic economists, presented at a hearing of the Senate Finance committee the following opinion: "The U.S. must take immediate high level action to avoid losing the world leadership in advanced technology--to lose in this competition would be extremely damaging to the economy and to national security" (Silk, 1983). The stated threat of this message is that this country is, in fact, losing ground in key world markets to countries that have forged ahead through close cooperation between business and government. This panel recommended that technological development be among the highest priorities in the nation. This position is articulated also by Bethe who suggests that nuclear power is essential to maintaining the economic strength and position of economic leadership of the United States (1977, 1979).

The combined economic and technological imperative is expressed in the perspective which refers to the "net social benefit." This perspective was

articulated by Starr, Chairman of the Electric Power Institute, and Whipple, a technical manager in a related organization (1980). This perspective does not actually address "safety" but focuses on "risk" instead in a manner implying a distinction between these terms. Lowrance (1976) delineates these terms in the following manner: measuring risk involves the probability and severity of harm and is defined by Lowrance as an empirical, scientific activity; judging safety or judging the acceptability of risks is defined as a normative political activity (Lowrance, 1976, pp. 75-76). This perspective maintains that risk, defined as qualitatively independent of safety, is a part of everyday life in an organized society, and that the critical questions are which risks have most overall social benefit, and how much risk will be acceptable to the public. Simply stated, safety is in the eye of the beholder, and risk is objectively measurable.

Starr and Whipple recommend an analytical approach, originated in cost-benefit analysis, for evaluating the "net social benefit" of technological risk. Simply stated, this approach may calculate risk of death as equal to the discounted net earnings of those killed, may evaluate cost of fatality in terms of numbers of survivors effected, or effect on the continuation of a family line.

Quantitative risk-benefit analysis may be defined as an integrated set of methodologies designed to assist rational decision-making, in instances where a complex array of inputs, outcomes, and uncertainties must be considered (Bogen, 1983). Numerous scientific publications have urged that this approach be employed by federal agencies in determining acceptable levels of risk for activities regulated by congressional mandate (National Academy of Sciences, 1982; Lave & Silverman, 1979; Gori, 1980; Okrent, 1980; Ricci & Molton, 1981). Government has apparently responded to this request as evidenced by President Reagan's Executive order 12291

which required agencies to subject all regulatory proposals to rigorous, and whenever possible, monitized quantitative cost-benefit analysis (Bogen, 1983). Senate bills and hearings have accordingly addressed the integration of cost-benefit analysis into the regulatory process (Dole, 1981; Laxalt, 1981; Ritter, 1981; U.S. House Committee on Science and Technology, 1980).

Within the "net social benefit perspective," public opinion has recently been acknowledged as a variable that must be considered presumably because there is a potential cost attached to it. Starr and Whipple (1980) maintain that the cost to society of the conflict over risk is great. These costs refer specifically to litigation and delays in operations. The realization of public reaction to nuclear energy as a financial reality has brought with it an interest in studying public perceptions of acceptable risk so as to better anticipate and ally anxieties associated with public perception of risk (Starr & Whipple, 1980; Slovic et al. 1982). The underlying target of some of this research appears to be acquainting policymakers with the nature of public reaction to risk. In the words of Slovic et al. (1982), "It would surprise and disturb us to learn that policymakers did not want to understand these reactions and concerns and consider them in their deliberation."

Starr and Whipple (1980) seeing a need for reducing cost associated with controversy suggest by-passing public controversy by establishing legislatively sufficiently low levels of acceptable risk below which no regulatory action would be taken. According to these authors, "this could be useful in allocating a regulator's time, and would help prevent the highly visible cases in which the nuisance aspects of regulation are intuitively greater than the benefits of that regulation" (Starr & Whipple, 1980). A move in the direction recommended by Starr & Whipple is reflected in the congressional amendment to the Atomic Energy Act, the Sholley Amendment

(Public Law 85-256, 1983) in which "safety" was legally separated from whether or not an event presents a "significant hazard consideration." The significance of this amendment is that if the Nuclear Regulatory Commission decides that an action by the nuclear industry does not present "significant hazard consideration," then conditions of the licensing act, which provide for a public hearing for considerations of safety prior to a decision to amend licensing restrictions, are waived. The similar principle of "de minimus," whereby there is a value below which risk should be ignored has also been applied in the U.S. Food and Drug Acts (Wilson, 1984). Wilson has pointed out that this approach presents a problem of potential regulatory hiatus in cases of risk uncertainty due to insufficient data (1984).

Awareness of public opinion as a cost factor, in addition to influencing legislation, has generated a growing body of psychological research which suggests that lay peoples' notion of "risk" may deviate from technical estimates and that lay judgments of risk are influenced by cognitive bases or "individual heuristics" which systematically bias perception (Cole & Withey, 1981; Tversky & Kahneman, 1981; Fischhoff et al., 1981; Lichtenstein et al., 1978; Otway & Fishbein, 1977; Otway et al., 1978; Slovic et al., 1979; Slovic et al., 1984; von Winterfeldt & Otway; Vlek & Stallen, 1981). This research identifies various kinds of bias, including a common tendency for individuals to overestimate infrequent causes of death while underestimating more frequent causes (Lichtenstein, Slovic, Fischhoff, Layman, and Combs, 1978). Some of this research is interpreted to mean that consideration of public perception of threat and the prevalance of risk should take into account the susceptibility of lay judgments to manipulations of mood, and the apparent lack of awareness of this effect (Johnson & Tversky, 1983). According to Fischhoff, et al. (1982), lay people seem to lack the intuitions and cognitive capacities in dealing with

complex, probabilistic problems. As a result they resort to judgmental heuristics, or rules of thumb that allow them to reduce such problems to simpler and more familiar terms.

Further analysis reveals, however, that differences between expert or formal and lay estimates of risk seem to correspond to different definitions of risk. When experts judge risk, their responses correlate highly with annual fatalities (Slovic et al., 1982). Lay people can assess annual fatalities if asked to and produce estimates not unlike technical estimates. However, their judgments of risk are sensitive to other factors (Slovic et al., 1982); von Winterfeldt et al., 1981). Studies that have looked at bias in estimating risk of catastrophe in fact show consistent bias in "expert" as well as nonexpert populations frequently in the same direction (Fischhoff, Slovic & Lichtenstein, 1981). However, the unstated but implied assumption in this literature has been that bias in experts is overridden by their access to empirically derived statistical data, such as annual fatalities for a given activity, illness, or industry which they are more apt to use in assessing risk (Fischhoff et al., 1978).

In contrast, Cole and Withey (1981), define risk among lay populations as "poorly calibrated" when compared with objective, statistical data. (Calibration referring to accurate estimates of annual fatality statics.) These authors conclude that subjects depend upon "individual heuristics" when evaluating potential risk, and that these heuristics systematically bias perceptions of risk. Thus, researchers have chosen to pursue what the lay population is responding to often with the assumption that, although systematic, it still represents error variance. For instance, Fischhoff et al. (1978) label one correlate of lay risk assessment "dread" which include variables such as severity not controllable, globally catastrophic, little preventive

control, certain to be fatal, threatens future generations, not easily reduced. Cole and Withey (1981) describe this as the individual's mental representation of technology which are is colored by one's "gut reactions" to selected aspects of this mental image. Von Winterfeldt et al. (1983) found that for lay populations individual fatality probability emerged as the best predictor of intuitive risk ratings with average fatality a unidimentional mortality statistic not relating at all. Disaster estimates were positively correlated with risk ratings for a subset of activities which had a low fatality probability and a large disaster potential.

Slovic, Fischhoff and Lichtenstein (1979, 1980) have shown that lay judgment of risk can be predicted by a combination of fatality estimates for an average year and estimates of the number of deaths that would arise from the most disastrous one could imagine happening in one's lifetime. These authors in ordering peoples' conceptualization of risk on a grid of 90 hazards and 18 qualitative aspects of risk, found that the 18 aspects of risk could be summarized by two underlying dimensions: novelty and mystery, and possiblity of uncontrollable consequences (1980). Voluntariness which has been previously identified as a factor in lay risk assessment (Whipple 1976) has been reconsidered as a surrogate for peoples' concern about catastrophic potential or equity (Slovic et al., 1980).

The quantitative analysis applied to public reasoning seems to lead some experts to ask in bewilderment..."today, there are risks from numerous small dams far exceeding those from nuclear reactors. Why is the one feared and not the other? (Wildavsky, 1979)." Wildavsky (1979, p. 34) reasons that nuclear energy is safer than solar energy because of the inefficiency of solar energy. "Since so much more effort per kilowatt generated is involved in producing solar panels and piping, the normal relative accident rate in industry is far greater for solar than nuclear power

production, and the evidence for the number of people falling off roofs or chemicals leaking into heated water is not in yet!" This process of "revealed preference" whereby the risk of a new technology is compared with that of a known and assumed, accepted technology is questioned by Wilson (1984). Reflected in this expert reasoning is unexamined acceptance of annual mortality statistic as the accurate, more objective assessment of actual risk, while defining consideration of catastrophe in a multidimensional way as error or bias.

The formal analysis has not systematically addressed the possibility that underlying the dread factor is an intuitive realization that catastrophic events are characterized by fewer degrees of freedom in a chain of events that impact on an individual, and that events of this sort are not mutually exclusive in the sense that probabilistic use of statistics would imply. Since the 1979 accident at Three Mile Island, there has been more awareness that the many physical and chemical processes that might occur during such an accident are not fully understood, nor is the possible synergistic effect of their occurrence (Davies, 1984).

The possible significance of unanticipated non-reversible chains of negative consequences of catastrophe has also been discussed in reference to partial destruction of ozone layer associated with nuclear explosion (Turco, Toon, AcKerman, Pollack and Sagan, 1983). However, the weight relegated to such unanticipated consequences of catastrophe remains an individual heuristics of lay assessment in the calibration of quantitative risk assessment.

Starr (1969) employed an analytic statistical approach based on the assumption that historical national accident records are adequate for revealing consistent patterns of fatalities in the public use of technology. Cole and Withey (1981) question this assumption of historical accuracy, and the assumption that what

is "best" for society is what is traditionally acceptable. These authors (Cole and Withey, 1981) acknowledge that the technologies in question may be imperfectly understood either in terms of their long-term operating characteristics or their secondary impact, but nevertheless, endorse a formal (statistical) approach so as to "structure the question at hand and, thereby, highlight the associated unknowns and imponderables" (Cole and Withey, 1981, p. 150).

Bogen (1983) includes among such unknowns and imponderables, variables that may never be completely quantifiable. Bogen (1983) suggests that reasonable expectations of harm can almost never be proven and quantified because of the nature of many environmental health risks in that harm may occur only after some delay and only in a few out of a large exposed population, making a casual link between the risk and a given individual practically impossible to demonstrate. The issue is compounded by the recent consideration by scientists that health effects can occur at very small doses of pollutants as illustrated by the linear dose-response relationships postulated with respect to radiation exposure (Wilson, 1984).

Although research has by no means restored faith in lay assessment of risk, balance has recently been restored by questioning of the infallability of expert opinion. Fischhoff et al. (1982) have summarized expert errors leading to underestimation of risk as the following: failure to consider the ways in which human error, such as daily management and management integrity, can effect technological systems; overconfidence in current scientific knowledge; failure to appreciate how technical systems function as a whole; slowness in detecting chronic, cumulative effects; failure to anticipate human response to safety measures; failure to anticipate "common-mode" failures. According to Fischhoff et al. (1982), experts do not differ from lay people in the way that they think but in the information that they

have available to them, and even this is not always an advantage. According to these authors, the price of acquiring depth of field may be a reduction in breadth of view. In addition, these authors point out that expertise in the field is so narrowly distributed that assessors are typically called upon to judge the quality of their own judgments.

The clarity of advantage of expert or formal analysis over lay analysis with its individual heuristics may also be questioned on a statistical basis. Because risk technologies are characterized by rapid change, they have relatively brief histories and most likely qualitatively different futures, and the predictive assumption of statistics that circumstances will remain constant does not hold. Wilson points out that risk does not stay constant with the example of increased risk of death incurred by a person who develops cancer (1984). Risk analysis lends itself to Bayesian statistics which allow use of information other than sample information, such as information from other comparable samples or simply from the statisticians' own opinions and beliefs about a particular state of affairs (Hayes, 1973). The Bayesian approach is reportedly appealing to those wishing to make practical decisions on the basis of statistical evidence (Hayes, 1973). This is presumably because it allows the estimation of values for unknown parameters of the decision, and thus allows the investigator to include all variables considered to be relevant amongst the priors of the analysis regardless of actual information available about these variables (Fischhoff & Beyth-Maron, 1983). Thus, Bayesian analysis provides tools for converting one's beliefs or hypotheses into guides for action whereby cost associated with erroneous acting as though a hypothesis is true, and cost of erroneously acting as though a hypothesis is false is defined as a critical ratio.

The Bayesian point of view has been criticized as being essentially subjective

as opposed to objective analysis in that the weight given to prior opinions about variables is nowhere dictated by theory (Hayes, 1973, p. 841). Since the end product of a particular analysis depends upon what a particular experimenter or statistician happen to think at the outset, each set of results is peculiar to the experimenter or statistician who happens to be doing the analysis (Hayes, 1973, p. 841). Thus, the effect of a piece of data or finding depends in Bayesian analysis on the initial hypothesis. One could in principle observe a datum strongly supporting a hypothesis that is initially very unlikely and leave one's posterior odds favoring it still very low, but not as low (Fischhoff & Beyth-Maron, 1983). Fischhoff & Beyth-Maron (1983) identify seven sources of error in Bayesian analysis including: "over-confidence" or failure of one's confidence to correspond with reality; treating component probabilities unequally by acting as though a hypothesis that probably is true is absolutely true effectively neglecting its compliment; and conservatism or failure to appreciate how diagnostic accumulating evidence is. Criticisms of this methodology have noted that it is impossible to insure that such a statistical model is complete since the basic statistical data needed to solve the model is unavailable and that although the model might be used to predict which of two systems is safer, it is an unreliable guide to actual future experience measured in real terms (Thompson, 1984).

The reaction of statisticians to possible misuse of Bayesian statistics in risk assessment is reflected in the statements presented at the Sixth Symposium on Statistics and the Environment. Raiffa (1982), Chairman of the National Academy of Sciences - National Research Council Committee on Risk and Decision-Making, argued for the need to separate risk assessment from risk evaluation on the basis that probabilistic reports about adverse consequences to health are very often

slanted to be conservative. According to Raiffa, experts are likely to disagree in their analyses because of slippage in vocabulary, different paradigms, cognitive biases, elicitation biases, and conscious self-interest or altruism. Wilson (1984) clearly differentiates between "Scientific data which are often but not always precise, from the calculation of risk which is less certain. He optimistically recommends that in risk calculation: the assumptions be stated clearly; they should calculate both the number and the uncertainty of the number; cost benefit comparisons should be adjusted by the value judgments of any interested parties; and experts point out risks that are probably underestimated so that the quality of life can steadily be improved (Wilson, 1984, 18, 20).

In summary, examination or risk assessment efforts thus far suggest the following:

1. National policy decisions made thus far have reflected an economic imperative, whereby economic cost is a better predictor of policy decisions than is consideration of human safety.
2. Justification on one level for these decisions has been that indirect costs of safety regulations to the consumer are greater than they are worth. On another less clearly articulated level, the assumption is that safety regulations represent an impediment to technology, the economic well-being of the nation, and hence our national security.
3. This logic is often associated with quantitative risk benefit analysis in which possible costs and benefits of policy decisions are quantified and assigned financial value.
4. There has been an increasing urging for governmental bodies to

incorporate risk benefit analysis and mandate it through legislation.

5. Increased awareness of public opinion has evolved as a result of unexpected strength of influence of public opinion on legislators, particularly through use of the media.
6. The "cost/benefit" perspective associates public opinion with possible unanticipated cost generated from conflict and time delays.
7. Increased interest in public opinion has been associated with increased interest in understanding of and predicting public perception of risk.
8. Research on lay risk assessment has focused on bias or individual heuristics that reportedly systematically bias the public's prediction of risk associated with hazardous events.
9. Research has identified as error variance a tendency for the public to attach more risk to catastrophic events that might not occur with great frequency, but for which there is an uninterruptible chain of negative consequences, the negative effect of which are not fully knowable.
10. More recently discussion has focused also on sources of expert bias and the infallibility of expert opinion based on quantitative methods has been increasingly questioned.
11. One line of questioning has been the use of Bayesian statistics as though it were entirely objective when in fact it is a method which allows for the systematic incorporation of data with subjective evaluation and opinion.

12. Dialogue on this issue has reached the point of acknowledging that quantification does not guarantee objectivity, and that expertise does not guarantee lack of bias.

13. There appears to be an increased awareness that even when experts have a near monopoly on the best available facts, they need not have a monopoly on a set of possibly valid perspectives, particularly with problems having complex social ramifications or involving the interaction of diverse systems (Fischhoff, 1982).

Where does this leave the question of risk assessment in a society that finds itself beset with unanticipated risks and not accustomed to dealing with uncertainty? Fischhoff et al. (1982) suggest that there is no way to get the right answer to many risk problems, and that all we can hope to do is avoid the mistakes to which each of us is attuned. The parable of the blind man and the elephant is brought to mind in which each of the men understands only the small portion of the elephant to which he is exposed. To the extent that this parable applies, policy decisions involving risk require the inclusion of, communication between and cooperation among diverse segments of our population. With this task in mind, we may perhaps be very watchful of biases to accept unquestioning definitions of expertise and models of analysis that may relate more to economic imperative than to the immediate decision.

Analysis on a meta-level suggests that when research is used for the determination of national policy that potentially impacts differentially on different sectors of society, conflict between these sectors may represent itself in discrepancies in the scientific community. According to Raiffa (1982, p. 237), Chairman of the National Academy of Sciences - National Research Council

Committee on Risk and Decision-Making, "something is wrong when the membership of prestigious committees, created to report on some natural science uncertainties and not on policy issues, must be structured to yield a balance of policy viewpoints rather than a balanced portfolio of scientific and methodological skills." Fischhoff (1982) maintains that the exigencies of the political arena, and provocation of the news media all encourage adversarial encounters that are inhospitable to properly qualified scientific evidence.

It is the thesis of this paper that it is not the exigencies of the political arena or the provocation of the news media that encourages adversarial encounters as suggested by Fischhoff but that these encounters reflect a structural reality that different sectors of our society are differentially impacted by the policy issues at hand. It is further suggested that the need for political balance in prestigious committees, rather than reflecting an aberration, reflects the reality that models of analysis and bodies of knowledge themselves reflect diverse values and perspectives of possibly adversarial sectors of society.

Finally, the intention of this paper is not to cast aspersions at any of the above-mentioned models or perspectives nor is it to offer an alternative solution. The paper is presented in the hope that stripped of our illusions of complete objectivity, impartiality, and invulnerability to powerful systemic forces, we can adopt an attitude of respect for the questions raised and humility in our approach to solutions.

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